




Laboratory Gas Migration Experiments through Intact and Fractured Rock

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**Sandia National Laboratories
Geoscience, Climate, and
Consequence Effects**

**Broome, S.T., Cashion, A.T.,
Feldman, J.D.**

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Outline

- ***Background and Motivation***
- ***Material and Sample Preparation***
- ***Test Equipment***
- ***Test Methods***
- ***Results and Analysis***
- ***Summary and Future Work***

Underground Nuclear Explosions Signatures Experiment (UNESE)

- **Detection, location, and identification of suspected nuclear explosions are United States security priorities**
- **Currently monitoring relies on networks of sensors providing prompt signals**
- **For UNE's, prompt signals may not provide sufficiently exact locations or explosion details**
- **Need for research to improve post-facto identification of suspect events with emphasis on non-prompt signals**
- **Non-prompt signal analysis can lead to improved understanding of the detected source**
- **Noble gas migration properties through surrounding geological formations are essential for any UNESE test bed**
- **Research presented will allow better understanding of the processes of noble gas migration through varying geologies**

Approach

Partially
Welded

Strongly
Welded

Vitric
Nonwelded

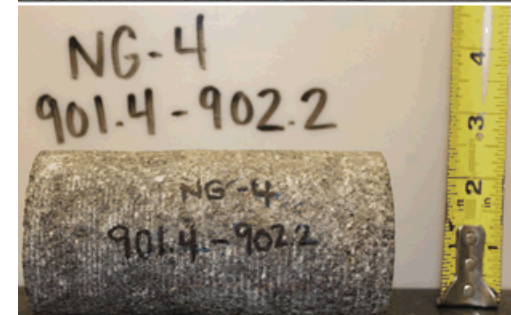
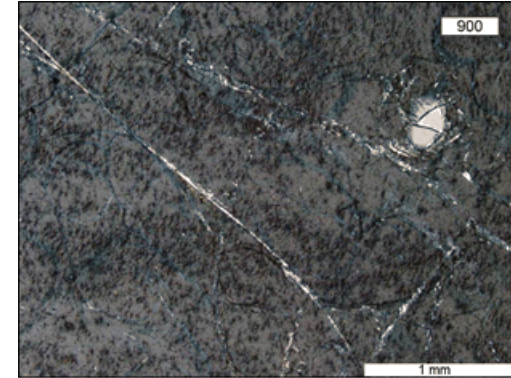
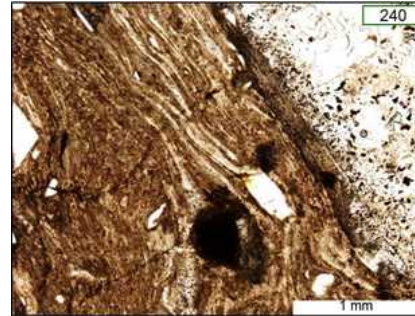
Rhyolitic
Lava

Zeolitic
Nonwelded



Sample Preparation

- Thin sections and core of samples for current study
- Depth 241 feet classified as strongly welded tuff
- Depth 901 feet classified as rhyolitic lava

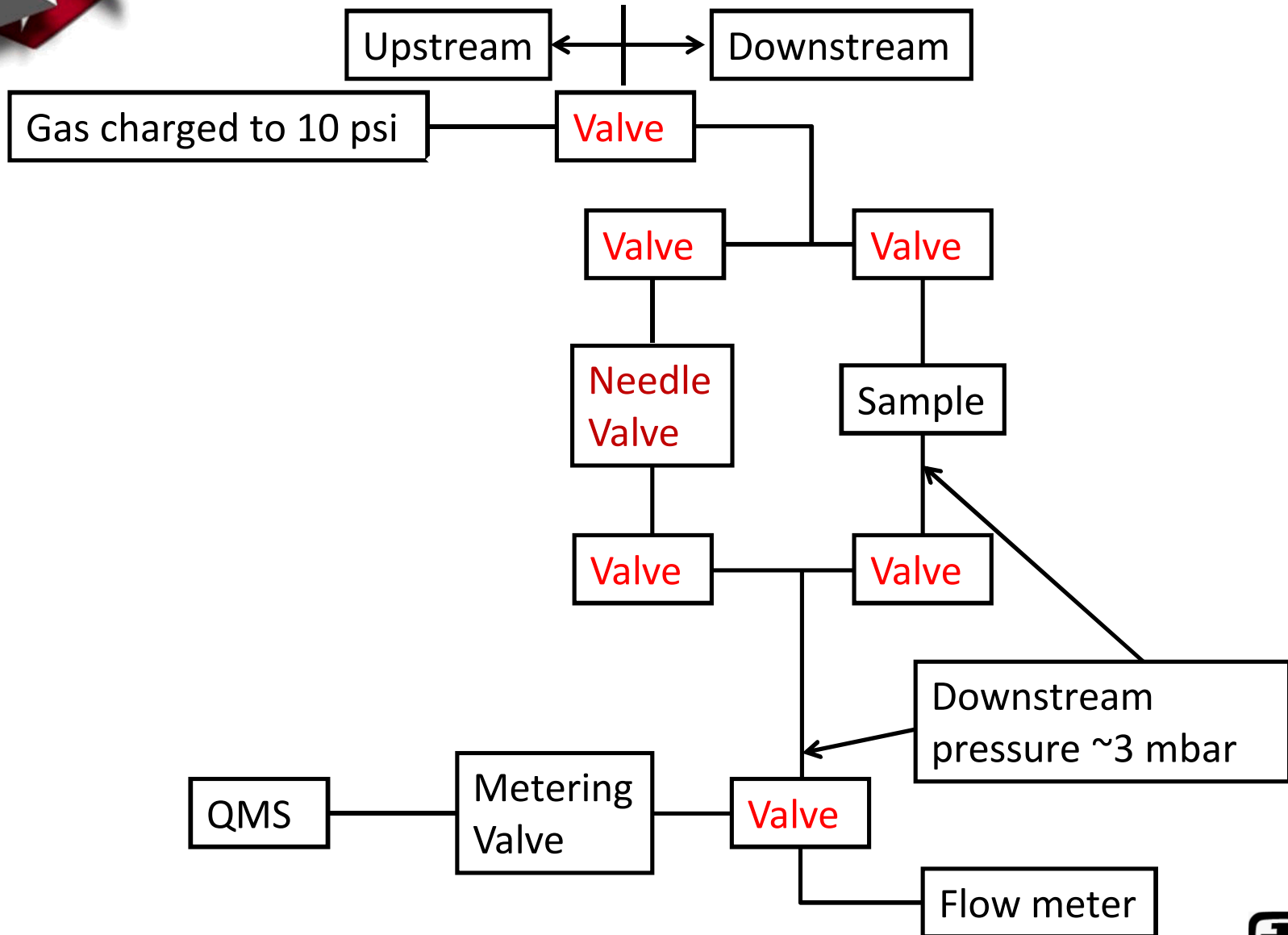


Sample Preparation

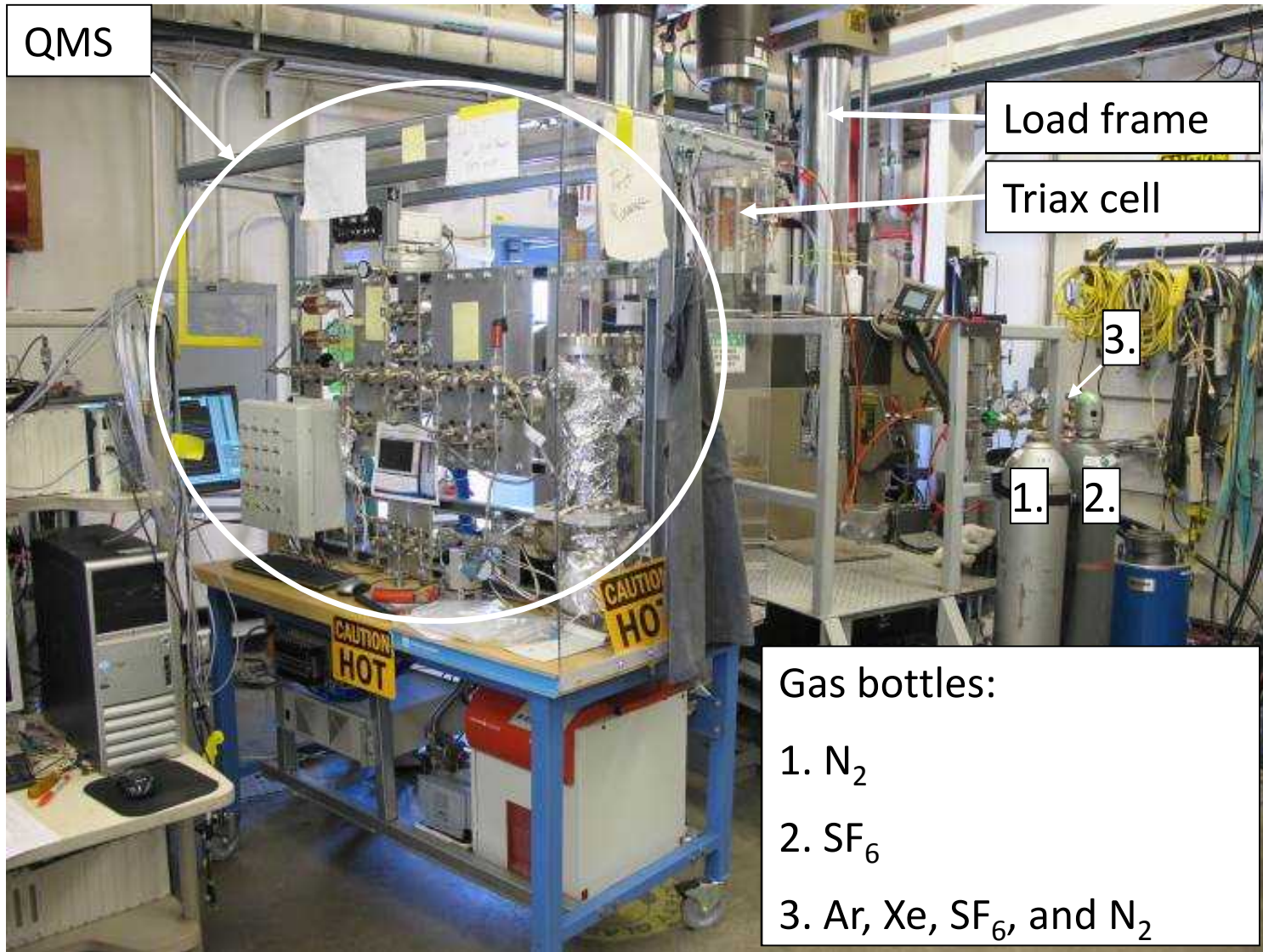
- Nominally 2.5 inches diameter
- Cut to ~1.9 inches in length
- Porous felt metal plates placed on ends of samples
- Jacketed with UV cure urethane to prevent gas seepage along wall
- One sample saw cut to compare against intact gas flow



Test equipment schematic



Test equipment

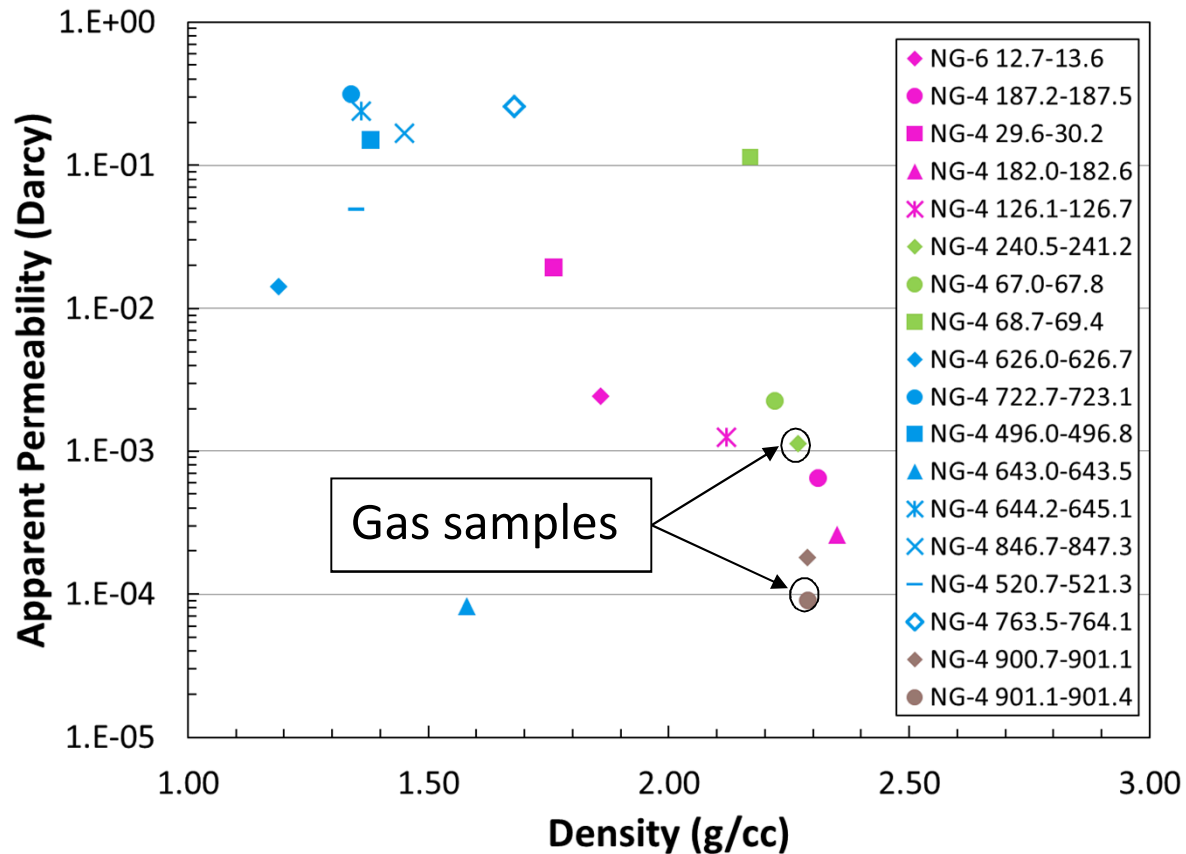


Test Methods

The methodology developed for measuring noble gas arrival times and concentration curves as a function of time adheres to the following steps:

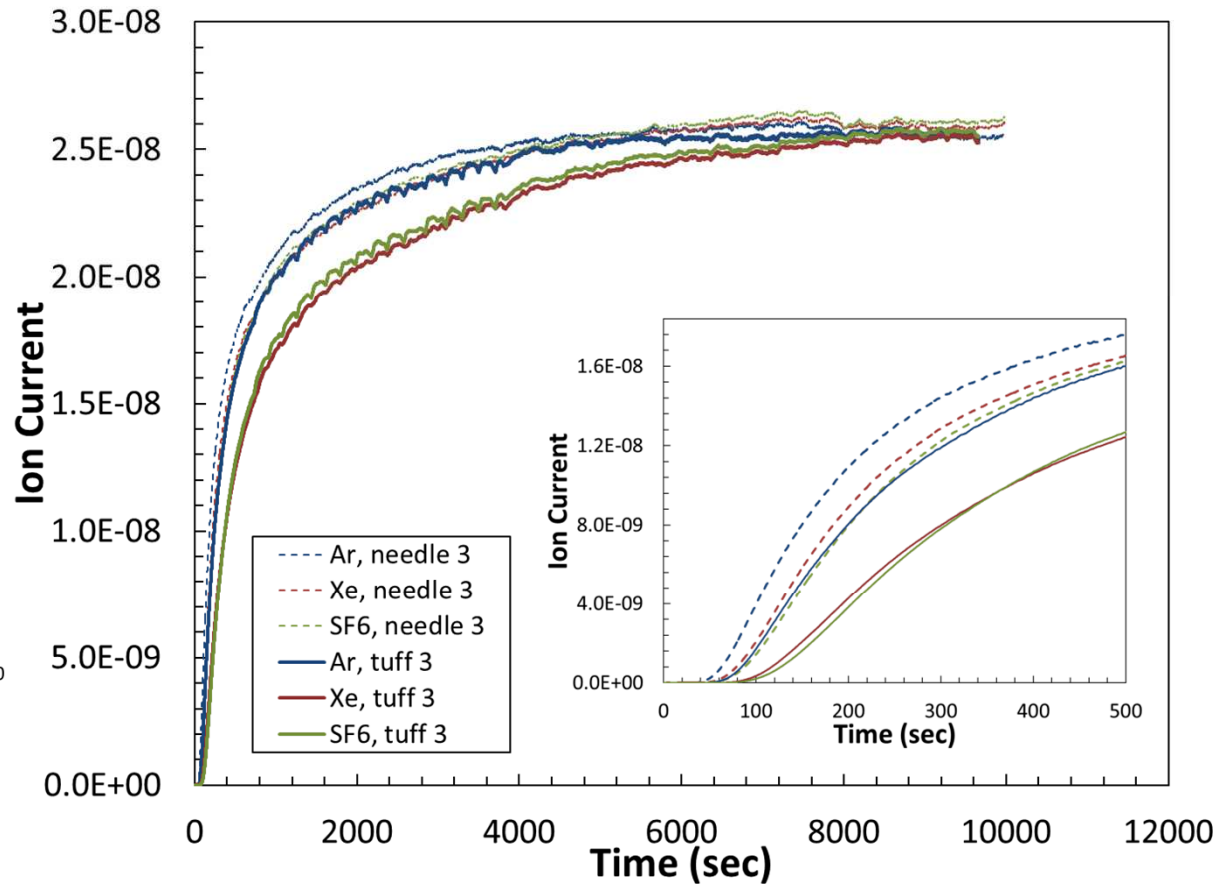
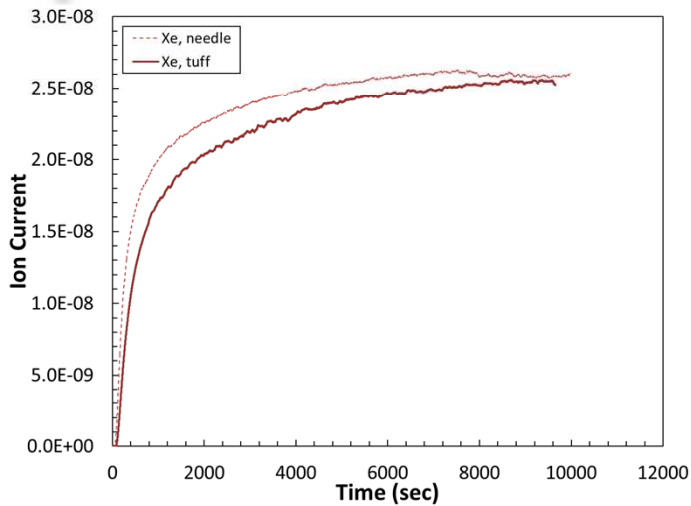
- 1) Samples are oven dried for a minimum of 24 hours
- 2) Prepared samples are placed into a triaxial cell and a confining pressure of 500 psi is applied
- 3) Nitrogen is flushed through the entire system
- 4) Roughing vacuum pump on the QMS used to bring system pressure down to approximately 3 mbar
- 5) QMS used to monitor nitrogen level of the test system. The system is deemed ready when $N_2 > 99.4\%$ to ensure nitrogen saturation within the sample and system
- 6) A known volume of gas (80% N_2 , 6.7% Ar, 6.7% Xe, 6.7% SF_6) is pressurized to 10 psi upstream of the sample
- 7) Valve separating upstream from downstream is opened
- 8) The QMS is set to detect specific primary isotopes of N_2 , Ar, Xe, and SF_6
- 9) Data are recorded until all gases have reached a near steady state concentration

Results and Analysis



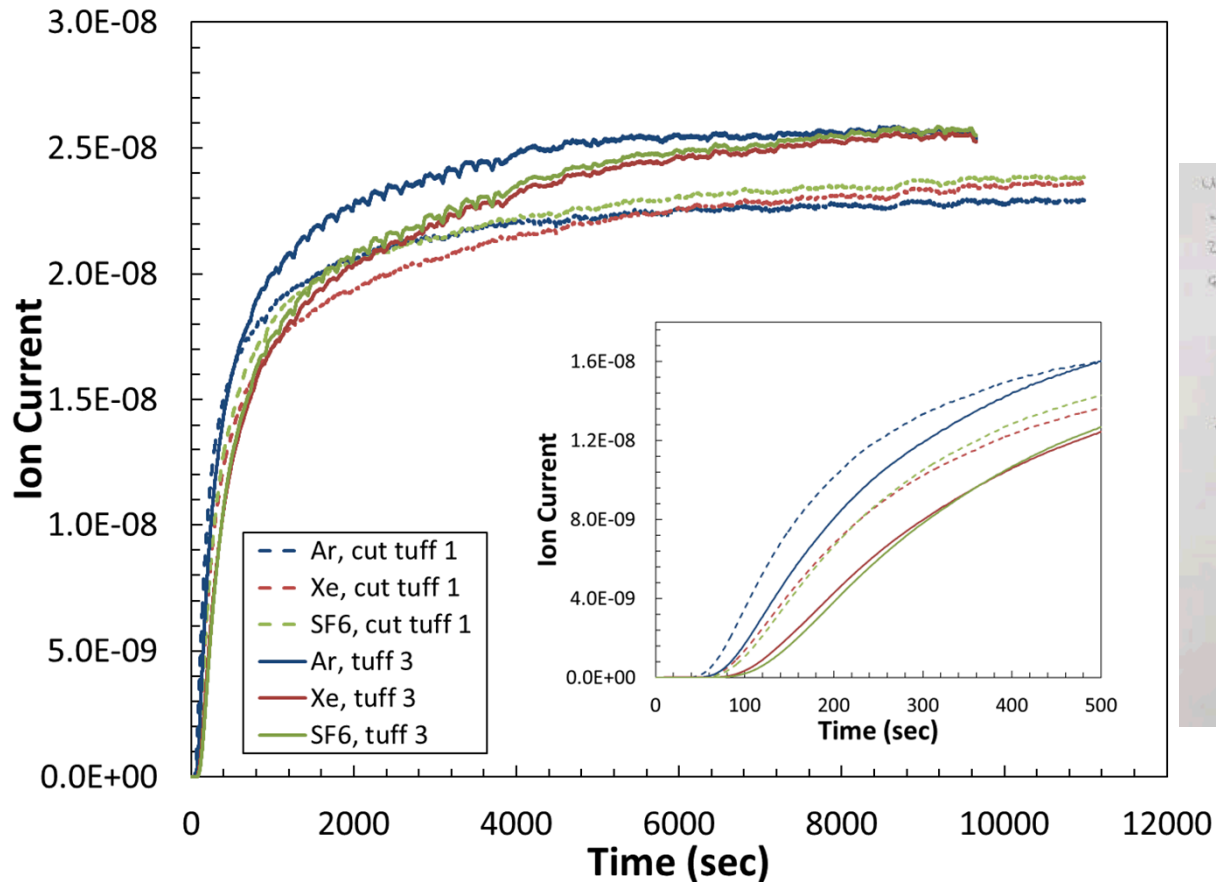
- Samples from permeability testing used for gas migration studies
- Porosities:
 - 8.8% (depth 241), 2.6% (depth 901)

Results and Analysis



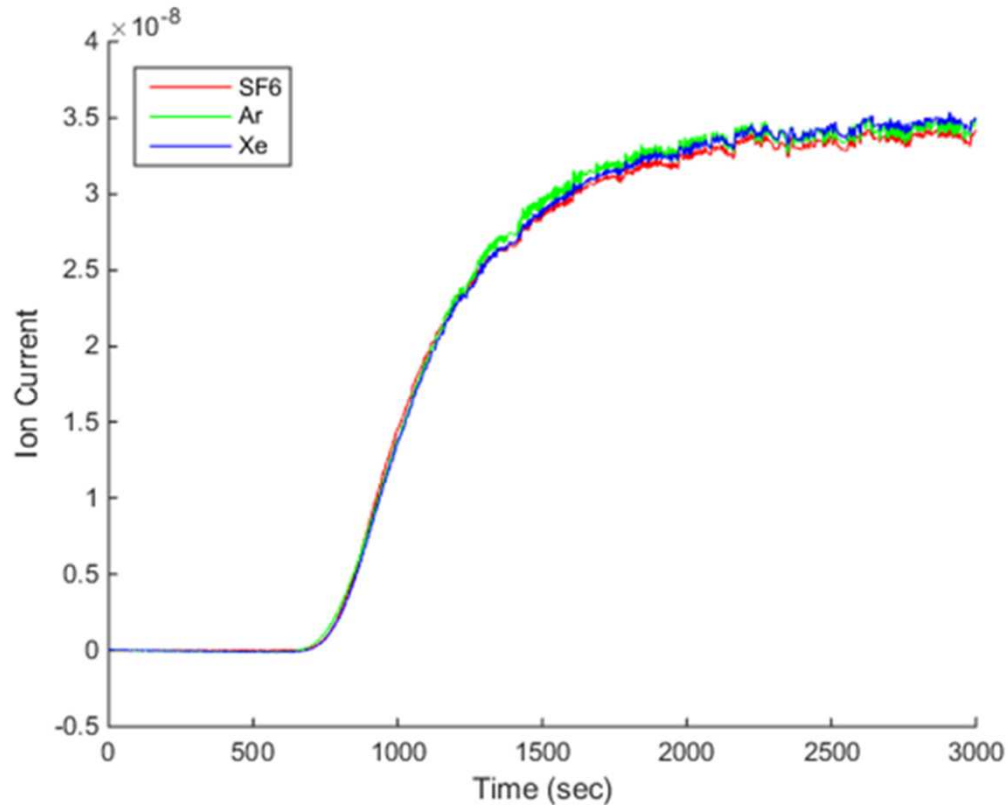
- To calibrate the system response, a needle valve was set to match N_2 permeability of each sample
- Arrival times are in order of noble gas mass

Results and Analysis



- Saw cut sample exhibits faster arrival times compared to intact sample
- Arrival times are in order of noble gas mass

Results and Analysis



- Sample at depth 901 has gas arrival time ~ 10 times slower than that of strongly welded sample
- Arrival times are in order of noble gas mass

Results and Analysis

Using Filter code with 0.5% threshold for arrival times

UNESE NG-4 240.5-241.2

Flow path	Arrival times		
	Ar	Xe	SF6
Needle valve (11-20-15)	44.6	60.7	63.3
Needle valve (11-30-15)	45.3	57.7	66.9
Needle valve (12-3-15)	46.3	58.4	64.6
Sample (12-2-15)	64.3	89.2	97.1
Sample (12-3-15)	65.6	86	95.1
Sample (12-7-15)	64.3	86.9	94.5

Needle standard dev	0.85	1.57	1.82
Sample standard dev	0.75	1.65	1.36
Needle average	45.4	58.9	64.9
Sample average	64.7	87.4	95.6
Needle coefficient of variation (%)	1.88	2.66	2.81
Sample CV (%)	1.16	1.89	1.42

Using Filter code with 0.5% threshold for arrival times

UNESE NG-4 240.5-241.2-saw-cut

Flow path	Arrival times		
	Ar	Xe	SF6
Needle valve (01-07-16)	37.7	48.6	55.1
Sample (01-07-16) run 1	49.9	65.6	68.9
Sample (01-07-16) run 2	49.9	63	67.9
Sample (01-08-16)	53.8	67.9	71.2

Sample standard dev	2.25	2.45	1.69
Sample average	51.2	65.5	69.3
Sample CV (%)	4.40	3.74	2.44



Summary

- *Initial laboratory based experimental efforts presented of noble gas migration to support an integrated field based program (UNESE)*
- *Future work will likely include*
 - 1) *Establishing tortuosity for varying lithologies*
 - 2) *Water content evaluation*
 - 3) *Pressure effects on intact and fractured samples*
 - 4) *Temperature effect upon pore and crack geometry*